APPROXIMATE DECLINATION & EQUATION OF TIME

	JANUARY		FEBRUARY		MARCH		APRIL		MAY		JUNE	
	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.
1	23° 01S	E0° 54'	17° 12S	E3° 24'	7° 44S	E3° 09'	4° 23N	E1° 01'	14° 57N	W0° 44'	22° 00N	W0° 36'
2	22° 56S	E1° 00'	16° 54S	E3° 27'	7° 19S	E3° 06'	4° 49N	E0° 57'	15° 18N	W0° 45'	22° 08N	W0° 33'
3	22° 51S	E1° 08'	16° 36S	E3° 29'	6° 57S	E3° 03'	5° 11N	E0° 53'	15° 31N	W0° 46'	22° 18N	W0° 16'
4	22° 47S	E1° 15'	16° 20S	E3° 30'	6° 35S	E2° 59'	5° 35N	E0° 48'	15° 52N	W0° 48'	22° 23N	W0° 28'
5	22° 38S	E1° 18'	16° 00S	E3° 31'	6° 11S	E2° 55'	5° 56N	E0° 43'	16° 10N	W0° 49'	22° 31N	W0° 27'
6	22° 33S	E1° 28'	15° 44S	E3° 31'	5° 47S	E2° 53'	6° 20N	E0° 39'	16° 26N	W0° 51'	22° 38N	W0° 23'
7	22° 26S	E1° 35'	15° 25S	E3° 31'	5° 24S	E2° 50'	6° 44N	E0° 34'	16° 45N	W0° 52'	22° 45N	W0° 21'
8	22° 17S	E1° 38'	15° 05S	E3° 32'	5° 02S	E2° 46'	7° 05N	E0° 30'	17° 00N	W0° 54'	22° 50N	W0° 18'
9	22° 10S	E1° 45'	14° 47S	E3° 33'	4° 37S	E2° 42'	7° 25N	E0° 25'	17° 15N	W0° 55'	22° 53N	W0° 15'
10	22° 01S	E1° 52'	14° 26S	E3° 34'	4° 14S	E2° 38'	7° 50N	E0° 23'	17° 32N	W0° 56'	22° 59N	W0° 12'
11	21° 50S	E1° 58'	14° 08S	E3° 35'	3° 53S	E2° 33'	8° 11N	E0° 18'	17° 48N	W0° 56'	23° 03N	W0° 09'
12	21° 42S	E2° 02'	13° 49S	E3° 34'	3° 26S	E2° 31'	8° 35N	E0° 14'	18° 03N	W0° 56'	23° 08N	W0° 06'
13	21° 33S	E2° 08'	13° 28S	E3° 34'	3° 03S	E2° 26'	8° 54N	E0° 11'	18° 20N	W0° 57'	23° 10N	W0° 03'
14	21° 21S	E2° 16'	13° 10S	E3° 34'	2° 41S	E2° 21'	9° 17N	E0° 06'	18° 33N	W0° 57'	23° 16N	0° 00'
15	21° 11S	E2° 21'	12° 49S	E3° 34'	2° 15S	E2° 17'	9° 40N	E0° 03'	18° 46N	W0° 57'	23° 18N	E0° 03'
16	21° 00S	E2° 27'	12° 25S	E3° 33'	1° 51S	E2° 14'	10° 00N	W0° 01'	19° 03N	W0° 57'	23° 19N	E0° 06'
17	20° 47S	E2° 32'	12° 08S	E3° 32'	1° 30S	E2° 09'	10° 23N	W0° 04'	19° 16N	W0° 56'	23° 22N	E0° 09'
18	20° 36S	E2° 37'	11° 44S	E3° 31'	1° 05S	E2° 08'	10° 44N	W0° 09'	19° 27N	W0° 56'	23° 25N	E0° 12'
19	20° 25S	E2° 41'	11° 25S	E3° 30'	0° 43S	E2° 01'	11° 03N	W0° 12'	19° 41N	W0° 56'	23° 25N	E0° 15'
20	20° 12S	E2° 46'	11° 02S	E3° 29'	0° 17S	E1° 56'	11° 22N	W0° 15'	19° 53N	W0° 55'	23° 24N	E0° 19'
21	19° 57S	E2° 49'	10° 43S	E3° 27'	0° 05N	E1° 51'	11° 43N	W0° 18'	20° 06N	W0° 54'	23° 27N	E0° 23'
22	19° 44S	E2° 54'	10° 20S	E3° 26'	0° 31N	E1° 47'	12° 05N	W0° 21'	20° 19N	W0° 53'	23° 27N	E0° 25'
23	19° 31S	E2° 59'	9° 56S	E3° 23'	0° 54N	E1° 42'	12° 26N	W0° 24'	20° 30N	W0° 51'	23° 25N	E0° 29'
24	19° 18S	E3° 01'	9° 33S	E3° 21'	1° 18N	E1° 38'	12° 43N	W0° 27'	20° 43N	W0° 50'	23° 24N	E0° 31'
25	19° 04S	E3° 07'	9° 12S	E3° 17'	1° 41N	E1° 33'	13° 06N	W0° 30'	20° 53N	W0° 49'	23° 23N	E0° 36'
26	18° 50S	E3° 10'	8° 47S	E3° 16'	2° 03N	E1° 29'	13° 24N	W0° 33'	21° 03N	W0° 48'	23° 22N	E0° 39'
27	18° 32S	E3° 12'	8° 30S	E3° 14'	2° 27N	E1° 24'	13° 44N	W0° 35'	21° 15N	W0° 46'	23° 21N	E0° 42'
28	18° 16S	E3° 16'	8° 06S	E3° 10'	2° 50N	E1° 19'	14° 05N	W0° 38'	21° 24N	W0° 44'	23° 19N	E0° 45'
29	18° 00S	E3° 18'			3° 14N	E1° 15'	14° 20N	W0° 39'	21° 33N	W0° 42'	23° 16N	E0° 46'
30	17° 46S	E3° 20'			3° 38N	E1° 10'	14° 40N	W0° 42'	21° 43N	W0° 41'	23° 12N	E0° 51'
31	17° 27S	E3° 23'			4° 00N	E1° 06'			21° 50N	W0° 38'		

	JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.	Dec.	Eq.
1	23° 06N	E0° 53'	18° 07N	E1° 33'	8° 25N	E0° 02'	3° 00S	W2° 31'	14° 19S	W4° 06'	21° 43S	W2° 43'
2	23° 03N	E0° 56'	17° 55N	E1° 33'	8° 06N	W0° 01'	3° 25S	W2° 35'	14° 37S	W4° 06'	21° 53S	W2° 41'
3	23° 01N	E0° 59'	17° 37N	E1° 32'	7° 42N	W0° 06'	3° 48S	W2° 41'	14° 57S	W4° 07'	22° 03S	W2° 35'
4	22° 56N	E1° 03'	17° 23N	E1° 32'	7° 21N	W0° 12'	4° 10S	W2° 46'	15° 16S	W4° 07'	22° 11S	W2° 30'
5	22° 49N	E1° 05'	17° 05N	E1° 31'	6° 58N	W0° 18'	4° 34S	W2° 50'	15° 32S	W4° 07'	22° 18S	W2° 25'
6	22° 45N	E1° 09'	16° 50N	E1° 29'	6° 37N	W0° 23'	4° 56S	W2° 54'	15° 52S	W4° 06'	22° 26S	W2° 19'
7	22° 37N	E1° 12'	16° 32N	E1° 27'	6° 14N	W0° 28'	5° 20S	W3° 00'	16° 10S	W4° 06'	22° 35S	W2° 12'
8	22° 32N	E1° 13'	16° 15N	E1° 25'	5° 52N	W0° 32'	5° 44S	W3° 05'	16° 27S	W4° 05'	22° 41S	W2° 04'
9	22° 25N	E1° 14'	15° 59N	E1° 23'	5° 30N	W0° 35'	6° 07S	W3° 10'	16° 45S	W4° 04'	22° 45S	W2° 00'
10	22° 19N	E1° 17'	15° 41N	E1° 20'	5° 06N	W0° 42'	6° 30S	W3° 13'	17° 00S	W4° 03'	22° 52S	W1° 53'
11	22° 11N	E1° 19'	15° 25N	E1° 18'	4° 45N	W0° 49'	6° 52S	W3° 15'	17° 18S	W4° 01'	22° 58S	W1° 44'
12	22° 01N	E1° 23'	15° 06N	E1° 17'	4° 21N	W0° 54'	7° 15S	W3° 20'	17° 34S	W4° 00'	23° 02S	W1° 39'
13	21° 54N	E1° 24'	14° 47N	E1° 14'	3° 57N	W0° 58'	7° 37S	W3° 24'	17° 51S	W3° 58'	23° 06S	W1° 32'
14	21° 44N	E1° 25'	14° 29N	E1° 12'	3° 34N	W1° 03'	7° 58S	W3° 29'	18° 08S	W3° 55'	23° 10S	W1° 25'
15	21° 37N	E1° 26'	14° 12N	E1° 09'	3° 13N	W1° 09'	8° 20S	W3° 32'	18° 22S	W3° 52'	23° 16S	W1° 17'
16	21° 25N	E1° 27'	13° 51N	E1° 06'	2° 48N	W1° 15'	8° 45S	W3° 34'	18° 38S	W3° 50'	23° 19S	W1° 10'
17	21° 17N	E1° 29'	13° 35N	E1° 03'	2° 25N	W1° 21'	9° 06S	W3° 36'	18° 53S	W3° 48'	23° 22S	W1° 03'
18	21° 05N	E1° 30'	13° 15N	E1° 00'	2° 03N	W1° 24'	9° 30S	W3° 42'	19° 07S	W3° 45'	23° 23S	W0° 56'
19	20° 55N	E1° 32'	12° 54N	E0° 57'	1° 40N	W1° 31'	9° 45S	W3° 44'	19° 23S	W3° 41'	23° 24S	W0° 48'
20	20° 46N	E1° 33'	12° 37N	E0° 52'	1° 16N	W1° 36'	10° 12S	W3° 46'	19° 35S	W3° 37'	23° 25S	W0° 41'
21	20° 35N	E1° 35'	12° 15N	E0° 50'	0° 52N	W1° 41'	10° 33S	W3° 48'	19° 50S	W3° 35'	23° 27S	W0° 33'
22	20° 23N	E1° 36'	11° 58N	E0° 44'	0° 29N	W1° 47'	10° 55S	W3° 50'	20° 03S	W3° 31'	23° 27S	W0° 24'
23	20° 10N	E1° 37'	11° 36N	E0° 41'	0° 05N	W1° 52'	11° 15S	W3° 52'	20° 16S	W3° 25'	23° 26S	W0° 18'
24	19° 58N	E1° 37'	11° 16N	E0° 36'	0° 17N	W1° 56'	11° 35S	W3° 54'	20° 28S	W3° 21'	23° 25S	W0° 11'
25	19° 44N	E1° 36'	10° 54N	E0° 33'	0° 40S	W2° 01'	11° 58S	W3° 57'	20° 41S	W3° 16'	23° 24S	W0° 02'
26	19° 31N	E1° 36'	10° 35N	E0° 28'	1° 05S	W2° 08'	12° 16S	W3° 59'	20° 52S	W3° 14'	23° 23S	E0° 04'
27	19° 19N	E1° 36'	10° 14N	E0° 24'	1° 28S	W2° 11'	12° 36S	W4° 02'	21° 02S	W3° 08'	23° 22S	E0° 12'
28	19° 06N	E1° 35'	9° 53N	E0° 20'	1° 52S	W2° 16'	13° 00S	W4° 03'	21° 13S	W3° 02'	23° 19S	E0° 19'
29	18° 50N	E1° 35'	9° 30N	E0° 16'	2° 15S	W2° 21'	13° 20S	W4° 04'	21° 24S	W2° 59'	23° 16S	E0° 26'
30	18° 38N	E1° 35'	9° 11N	E0° 13'	2° 38S	W2° 28'	13° 39S	W4° 05'	21° 36S	W2° 53'	23° 12S	E0° 35'
31	18° 23N	E1° 34'	8° 48N	E0° 08'			13° 57S	W4° 06'			23° 07S	E0° 41'

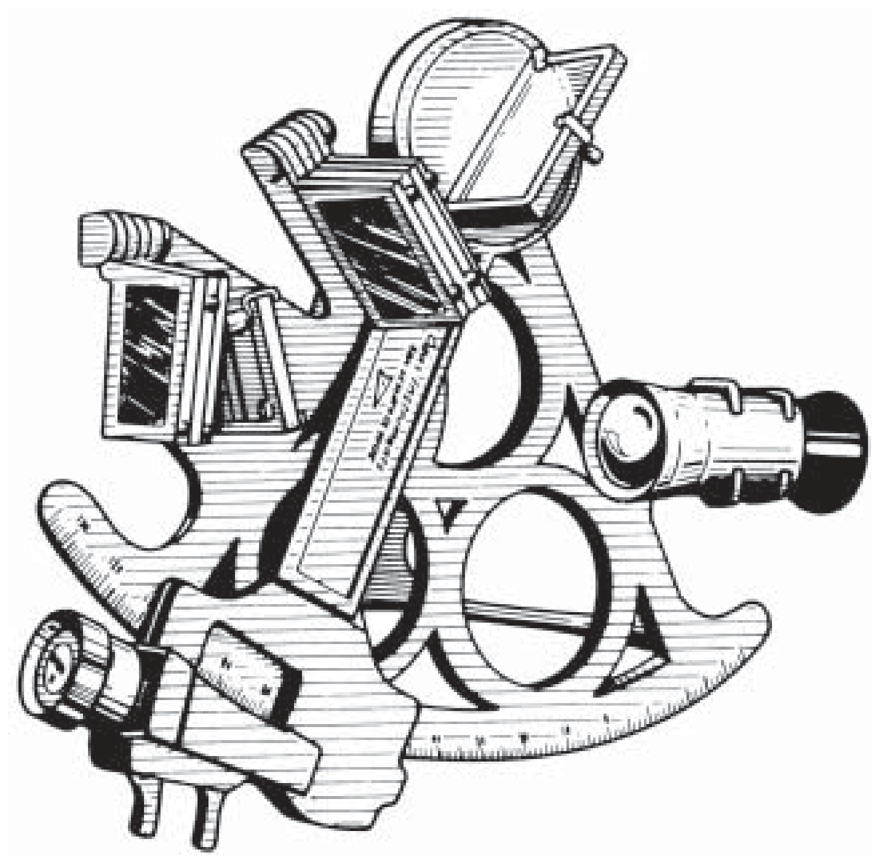
Equation of Time = True Sun E or W of the Mean Sun

Declination = Sun N or S of the Equator

Burnaby Power & Sail Squadron

A Member of the Canadian Power & Sail Squadrons - Pacific Mainland District

How to use a sextant



THE SEXTANT AS A PELORUS

Your sextant may also be used to find your position by sighting known land objects such as lighthouses, small harbours, or any other land features that are clearly recognizable on the chart. Pick out three features on the land. With the sextant held horizontally, measure the angle between the centre feature and one of the other features, and note the angle on a piece of paper. As quickly as you can, measure the angle between the centre feature and the third feature. Lay out the three angles on a piece of tracing paper so that the angles have a common centre point. Move the tracing paper around on the chart until the lines are positioned so as to run through the three features. The point of intersection of the three angles is your position (Fig. 15).

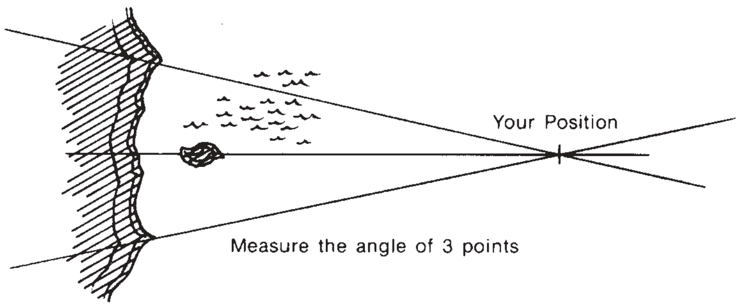
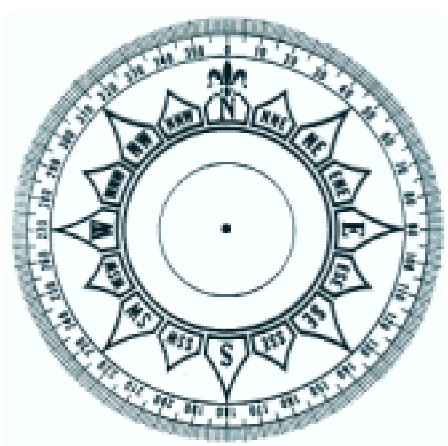


Fig. 15

Since the sextant does not have a compass, you do not need to worry about variation or deviation. However, you must use at least three lines of position.



How to use a sextant

HOW TO USE YOUR SEXTANT

This booklet has been written so you might learn how to operate a sextant, how to find the altitude of the sun, and how to use your readings to calculate location.

Though this Guide was originally written as an instruction manual of the Davis Mark 15 and 25 sextants produced by Davis Instruments, Hayward, CA, and references to these models appear throughout its pages, the instructions and guidelines apply to most any sextant you may encounter.

The meridian transit method of navigation used here is both easily learned and simply applied, and when you finish reading, we hope some of the mystery surrounding celestial navigation and sextant use will disappear. Before becoming an accomplished navigator, however, you will need to study those aspects of navigation which are beyond the scope of this booklet.

DESIGNS

The difference between sextants is most easily noticed when observing their horizon mirror. Some models like the Mark 15, use a half silvered horizon mirror, while others use full converging images like the Mark 25.

In this respect, perhaps the most significant design advanceme Davis incorporated in its Mark *25* is the “full-field dielectric Beam Converger”, invented by noted navigator-scientist, Angus MacDonald, D.Sc. The Beam Converger replaces the conventional half silvered horizon mirror, and gives you easier and more reliable sightings - under even the most adverse conditions.

“Full-field” means that you observe the sun or star and the “full” horizon simultaneously. The conventional horizon mirror reflects the celestial body most strongly in the silvered half of the mirror, while you view the horizon only through the clear, or non-silvered, half of the mirror. With the full-field Beam Converger, the reflected image of the sun or star is superimposed directly onto the observed horizon across the entire mirror. There is no “split image”.

“Dielectric” refers to the layers of materials deposited onto the mirror. These material layers become colour selective—the light of the sun or star is seen in one dominant colour region, and the light of the horizon in another. The increased contrast allows better sights at dawn and at twilight and under some conditions of daytime haze. The dielectric materials are also extremely durable. Your Beam Converger contains no metals or other reactive materials, and is nearly impervious to salt spray.

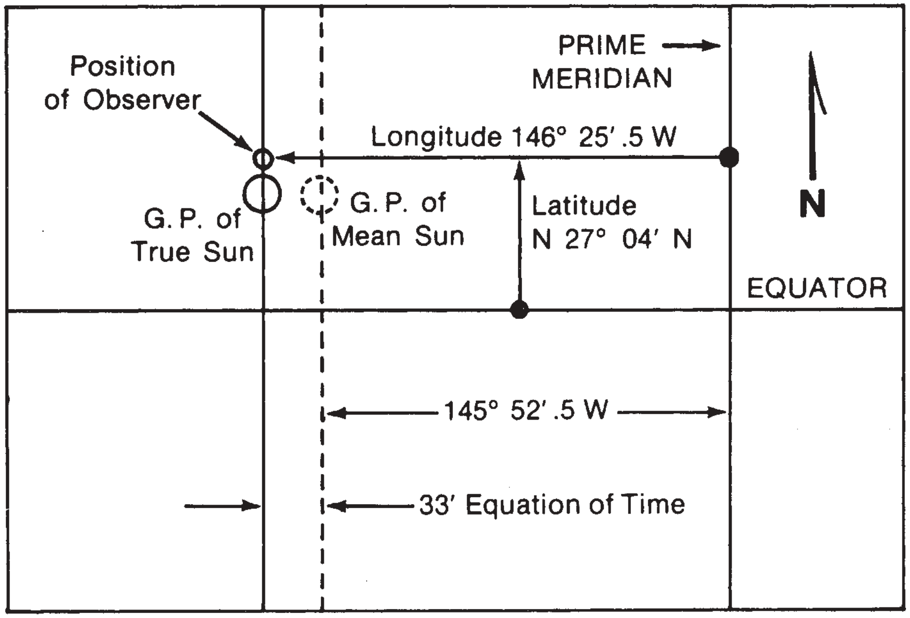


Fig. 13(c) Position Plot on chart

SYSTEMS OF CELESTIAL NAVIGATION

The method described above for calculating your position is the oldest method used since the introduction of the chronometer. Please note the following:

I. Latitude may be determined at noon if you know the corrected altitude of the sun and its declination. You need not know the time. The accuracy of your calculation is limited only by the accuracy of measurement of the sun’s altitude and by the accuracy of the declination tables.

2. To determine longitude, you must know both the time of observation and the equation of time. While your sextant gives highly accurate measurements, practical difficulties inherent in this method normally preclude accuracy of more than 10' of longitude.

A generalized system of position determination which enables you to use observation of the sun and other celestial bodies made at times other than noon requires knowledge of the navigation triangle, circles of equal altitude, assumed position, and associated navigation tables such as the Nautical Almanac and Sight Reduction Tables. These systems of celestial navigation are thoroughly studied and extensively used by serious navigators throughout the world.

Davis Instruments publishes a complete set of work forms for the H.O. 229, 249 (Vol.1) and 249 (Vol. II-III) Sight Reduction Tables, with step-by-step instructions. Nearly all navigators use work forms such as these to prevent errors and omissions in

ensure that you are never reading the incorrect whole degree; full accuracy in minutes of arc depends exclusively on the drum scale. For example, when the sextant reads 0º 00', the drum scale will be set precisely at zero, while the index line and the zero on the arc may be slightly out of alignment. As you are concerned only with reading whole degrees on the arc, this difference is not significant.

USE OF LIGHT ON YOUR SEXTANT

Some sextants (Mark 25) are specially constructed with a solid State light emitting diode (LED) and light guide to allow easy reading of the scales at twilight. To use, just press the button at the top of the handle; the light turns off when the button is released. Make sure that your eyes are dark-adapted before using the light.

For practical purposes, this light source will last forever. The high efficiency, high intensity LED has a half-life of approximately 10 years. This means that if the light were operated continuously, it would take 10 years for its brightness to decrease by half.

Batteries used with a LED will last up to 10 times longer than they would if used with regular bulbs. To avoid corrosion on internal parts, remove the batteries from your sextant if you will not be using it for some time.

While most battery contacts on sextants are corrosion-resistant, invisible oxidation on the contacts and on each end of the batteries may occasionally prevent the light system from working. If you are having operating difficulties, try gently cleaning the contacts with a knife blade, a file, or an eraser. If greater contact pressure seems to be required, gently bend the spring contact towards the battery with the tip of your finger.

CARE OF THE BEAM CONVERGER

The dielectric materials on the Beam Converger are nearly impervious to marine corrosion—the Beam Converger can be left in salt water for extended periods of time with no apparent effect. However, if salt spray is allowed to dry on the Beam Converger, a permanent light stain may result. To prevent these stains, clean both sides of the Beam Converger with a soft lens tissue as soon as possible after use. Use tap water, distilled water, or alcohol as necessary.

CARE OF THE INDEX MIRROR

The index mirror on the sextant should be fully coated on both back and sides with special salt-resistant materials. In most cases a high-density polyethylene pad protects this coating from the mirror adjusting screw. For the longest life of your index mirror, clean the front of the mirror with a soft lens tissue as soon as possible after use. As with the Beam Converger, use tap water, distilled water, or alcohol for more thorough cleaning as necessary.

moves around the earth at an average speed of 15° per hour (15 nautical miles per minute), longitude may be calculated by comparing local noon with Greenwich Mean Time (Fig. 13a). For example, if local noon occurred at 2:00 GMT, your longitude is approximately 30° west of Greenwich (2 hours x 15° / hour=30°).

While the above method gives your approximate location, you must apply the equation of time to determine your exact position. The earth in its orbit around the sun does not travel at a constant speed. Clocks and watches, therefore, keep the time of a fictitious or mean sun which travels at the same average speed throughout the year; the position of the true sun (as seen from the northern half of the earth) is not always due south or 180° true at noon by the clock. The difference in time between the true sun and the mean sun is called the "equation of time". The equation of time for any given day may be found in a Nautical Almanac; its approximate value may be found in the student tables at the end of this booklet.

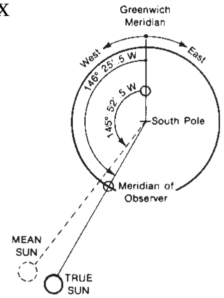


Fig. 13(a) Longitude Diagram (View of Earth Looking at South Pole)

Example: The Longitude Calculation **Longitude: 2 June**

21 h 43 m 30 s	GMT of local noon (from observation above)
- 12 h 00 m 00 s	Greenwich noon
09 h 43 m 30 s	Time from Greenwich to your ship
× 60	Minutes/hour conversion
583.5 m	Minutes from Greenwich to your ship
× 15	G.P. of sun travels 15 minutes of arc/minute of time
8752.5 m	Minutes of arc (nautical miles) from Greenwich
÷ 60	Minutes/degree conversion
145° 52′.5 W	Longitude position of mean sun
+ 33′.0 W	Equation of time for 2 June (from student tables)
146° 25′.5 W	Longitude of observer

FINDING LATITUDE

The altitude of the sun at local noon may also be used to calculate latitude. First, the measured altitude must be corrected for index error, height of eye, refraction, and semi-diameter. Refraction correction is negligible for altitudes above 25°**,** while the semi-diameter correction averages +0" 16'. (Semi diameter correction adjusts the sextant reading from an observation of the lower limb of the sun to one of the centre of the sun; 16' equals one-half the sun's diameter.) After the corrections are made, determine

raise the instrument to your eye. Look at any horizontal straight edge (for example, the sea horizon or the roof of a building) and move the index arm back and forth using the quick release levers. The real horizon will remain still while the reflected horizon will appear only when the arc and drum scales read close to zero. Line up the reflected horizon and the real horizon with the knob so that both appear together as a single straight line (Fig. 3).

Fig. 3
(a) Mirror horizon is not aligned with real horizon — index arm is not in proper position.
(b) Mirror horizon and real horizon form a single straight line — index arm is properly positioned.

Now without changing the setting, look through the sextant at any vertical line (for example, a flag pole or the vertical edge of a building) and swing the instrument back and forth across the vertical line. If the horizon mirror is not perpendicular to the frame, the line will seem to jump to one side as the mirror passes it. To correct this, slowly tighten or loosen the screw closest to the frame at the back of the horizon mirror or Beam Converger, until the real and reflected vertical lines perfectly coincide and no longer appear to jump (Fig. 4). In the case of the beam converger this is particularly easy since the two images have different colours. It is simply a matter of putting one image exactly on top of the other.

Fig. 4
(a) Double Image — Beam Converger screw too tight or too loose.
(b) Single Image — Beam Converger screw correctly adjusted.

INDEX ERROR ADJUSTMENT

Finally, remove the index error. Set the sextant to 0° 00, and look at the horizon.

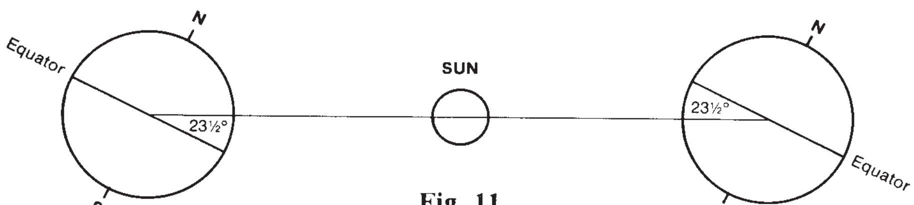


Fig. 11
Declination of the Sun

In like manner, each star has a ground position and a declination. The declination of Polaris is 89º O5'N; it is nearly directly above the North Pole. In the Northern Hemisphere, you can find your approximate position by taking a sight on Polaris. The reading will vary depending upon the time of night but will never be more than 55 miles off. This is a useful check each evening; the altitude of Polaris will be your approximate latitude without adding or subtracting anything. If you were to find the altitude of Polaris in the evening and again at dawn, your true latitude would be between the two measurements, providing you did not change latitude between the two sights. It is, of course, possible to calculate one's exact latitude from Polaris with the aid of the Nautical Almanac, but such a discussion is beyond the scope of this booklet.

To find Polaris, locate the pointers of the Big Dipper (Fig. 12). Find a point in line with the pointers and five times the distance between them. There, shining alone, is Polaris. The Big Dipper revolves around Polaris so be prepared to see the diagram in any position.

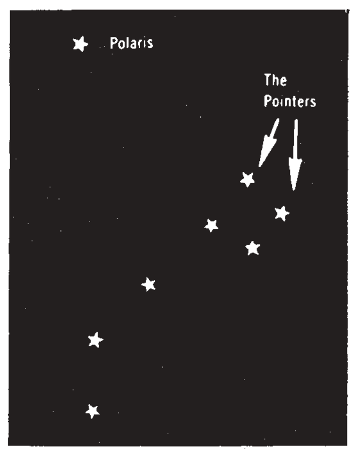


Fig. 12

FINDING LOCAL NOON & THE SUN'S ALTITUDE AT MERIDIAN PASSAGE

A meridian is an imaginary line drawn on the earth's surface from pole to pole; a local meridian is one which passes through the position of an observer. When the sun crosses the local meridian, it is at its highest point. It is said to be in meridian passage and the time is local noon. Local noon may vary a half an hour (and in daylight savings time, one and one half-hours) from the noon shown on the clock, due both to the equation of time (to be discussed later) and to the fact that our clocks are set to zone time. All clocks in a zone 15º wide show the same time.

To find local noon, follow the sun up with a series of sights, starting about half an hour before estimated local noon. Note the time and the sextant reading

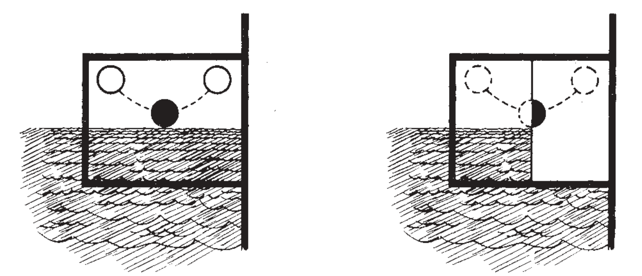
subtracted; if the sextant reads -6', the 6' is added. (Note: for an index error of -6', the micrometer drum will read 54'**.)**

MEASURING THE SUN'S ALTITUDE

Before looking at the sun through your sextant, be sure to position a sufficient number of index shades (the large set of shades) between the two mirrors to protect your eyes from the direct rays of the sun. Choose whatever combination of shades gives you a clear image of the sun without glare. All four index shades are normally used with a bright sun. If you are taking a sight under conditions of glare or when the sun is near the horizon, you may wish to use the horizon shades to darken the view of the horizon. The horizon shades are used to darken the clear section of the horizon mirror so that it acts as a semi-mirror. The horizon will still be visible through it, but the sun's image will be reflected.

To measure the sun's altitude, stand facing the sun with the sextant in your right hand. With your left hand on the quick release levers of the index arm, look through the eyepiece at the horizon and move the index arm until the sun is visible through the two mirrors and index shades. Release the levers and, while slowly rocking the entire sextant from side to side, use the fine adjustment drum to bring the sun's image down to just touch the horizon with its lower edge (lower limb). The sun's image should travel in a short arc that is made to touch the horizon (Fig. 7). Being careful not to disturb the setting, read the sun's altitude from the scales on the sextant. Since all calculations in the Navigation Tables use the centre of the sun or moon, this lower limb reading must be adjusted for semi-diameter correction, as shown later.

Fig. 7
The sun's image travels in an arc which just touches the horizon.



(a) Beam Converger **(b) Split Horizon Mirror**

For comparison purposes, the sun's image and horizon are also illustrated as viewed in a conventional sextant using a half-silvered horizon mirror.

HEIGHT OF EYE

When measuring the altitude of the sun, we want to measure the angle formed by a ray from the sun and a plane tangent to the earth at the point where the

The Burnaby Squadron Boating Guide Series is a public contribution from the Burnaby Power & Sail Squadron, a member of the Canadian Power & Sail Squadrons, Pacific Mainland District, to the advancement of "Safe Boating through Education".

The Boating Guides are the result of articles and instructional material prepared by members of the Burnaby Squadron, and contributions received from other members of the Canadian Power & Sail Squadrons and United States Power Squadrons.

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Following the sequence begun with a History of the Sextant, we offer this next Guide, reproduced with permission from the manuals for the Mark 15 and 25 Sextants, produced by Davis Instruments. Its purpose is to introduce the reader to the operation and multiple applications of a sextant.

Although many models of sextants offer higher precision and added features, the models described in this Guide possess all the essential characteristics to enable a sailor to navigate with confidence practically anywhere around the world.

We hope you will find instruction and it will wet your appetite to further study the applications of this little known navigation instrument, essential to any sailor till not long ago.

Davis Instruments can be contacted visiting: http://www.davisnet.com

THE SEXTANT AS HELIOGRAPH

The sextant mirrors may be used to flash the sun's rays several miles to attract attention, or to signal another person who is too far away for your voice to reach. If you know Morse code, you may even send a message. Hold the sextant so that the index mirror (the larger of the two mirrors) is just below the eye. With your other arm extended and the thumb held upright, look at the person you wish to signal. Bring your thumb to a position just below the person, so that your eye (with the mirror under it), your thumb, and the person to be signalled are in a straight line (Fig. 16). Using the mirror, flash the sun on your thumb; the sun will flash simultaneously on the distant person.

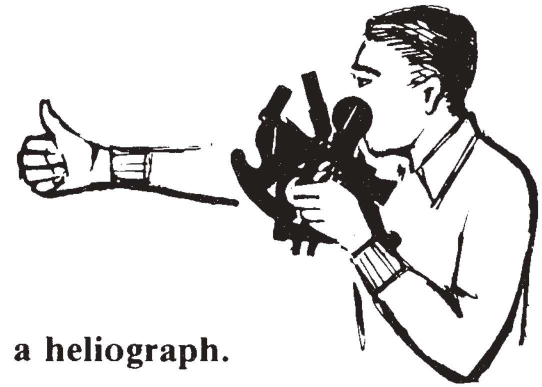


Fig. 16

Using the sextant as a heliograph.

STUDENT NAVIGATION TABLES

The tables on the following page give the approximate declination and equation of time of the sun. Latitude calculated with these values will be accurate to about ± 15'. The tables are thus intended for study purposes only, although they may be used for emergency navigation.

Davis Instruments, is a company founded in 1963 by Bill Davis, purchased six years later by Bob Selig and Jim Acquistapace, located in the San Francisco Bay Area. It manufactures and distributes three distinct lines of products. Weather, DriveRight and Marine. The Marine line includes, handheld sextants, wind vanes, telltales, and other plotting and sailing accessories. Its products are found in use around the world, from Europe to Asia, and from far northern Alaska to the tip of South America. To contact them for their products visit: http://www.davisnet.com .

READING THE SCALES

The index arm of the sextant may be moved in relation to the body by turning the micrometer drum or by squeezing the spring-loaded quick release levers. The levers free the fine adjustment screw in the interior of the index arm and allow it to be moved quickly to any angle. Be sure to squeeze the levers completely so that the screw clears the gear rack on the underside of the sextant. Upon releasing the levers, turn the micrometer drum at least one full turn to ensure that the screw has meshed fully with the gear rack. An incorrect reading may be obtained at the drum if this is not done. Also, because every sextant exhibits some difference in readings when turning toward higher or lower angles (called backlash error) always make the final movement of the knob toward a higher angle.

Some sextants like the Davis Mark *25* have three scales, allowing readings to 2/10 of a minute. The scale on the frame is called the “arc”; each division of the arc equals one degree. To read the number of degrees, find the lines on the arc that are closest to the index line on the index arm. The index line is usually somewhere between two lines. The correct reading is usually that of the lower value, i.e., the line to the right of the index line. When the index line is very close to a line on the arc, check the reading at the micrometer drum to be sure that you have taken the correct whole degree.

To read fractions of a degree, use the two scales involving the micrometer drum at the side of the index arm. The outer revolving drum scale indicates minutes of arc (one minute equals l/60 of a degree), while the stationary vernier reads to 2/10 of a minute. To read the number of minutes, find the single LONG line at the top of the vernier. The line on the drum scale that is opposite this line gives the number of minutes. (If the line on the vernier is between two lines on the drum, choose the line of lower value.) To read fractions of a minute, find the SHORT line of the vernier that is opposite to a line on the drum. Count the number of spaces this line is away from the long line at the top of the vernier. Each one equals 2/10 of a minute. In the diagram (Fig. 1), the line on the vernier that is opposite to a line on the drum is three spaces away from the long line at the top of the vernier. The sextant reads 45°16'.4.

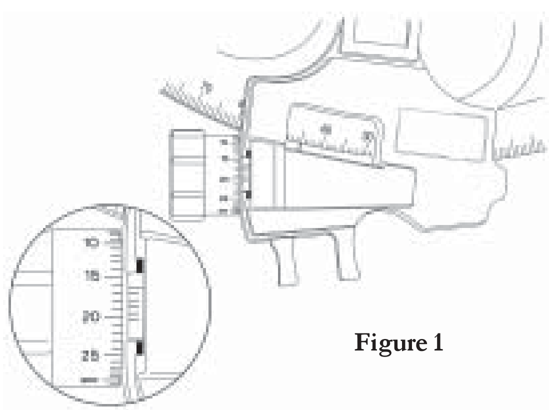


Figure 1

The micrometer drum scale and its screw mechanism determine the accuracy of your sextant, not the arc. The arc is stamped with sufficient accuracy to

the calculation of celestial navigation problems.

THE ARTIFICIAL HORIZON

At times, it is not possible to see the natural horizon. Sun or moon shots may still be taken, however, with the aid of an artificial horizon, a simple device containing water or oil shielded from the wind (Fig. 14). It may be used by individuals exploring inland far from the sea, or by students or experienced navigators who wish to practice celestial navigation without traveling to large bodies of water.

To use the artificial horizon, position it on level ground or other steady place. One end of the artificial horizon should face directly into the sun so that a shadow is cast at the opposite end; the sides and end facing the sun should be shadow-free. Looking into the centre of the liquid, move your head about so that you can see the sun reflected on the liquid surface. Now, placing your sextant to your eye, move the index-arm of the sextant until you see two suns - one reflected on the liquid and a double-reflected image on the mirrors. Line the two suns up by continuing to move the index arm. For a lower limb observation, the bottom of the mirror image should be brought into coincidence with the top of the image on the liquid. After the observation has been made, apply the index correction. Halve the remaining angle and apply all other corrections (except for dip or height of eye correction, which is not applicable) to find the altitude of the sun.

Since the sextant reading made with an artificial horizon must be halved. The maximum altitude that may be observed with the artificial horizon is equal to one-half the maximum arc graduation on your sextant. There may be several hours around noon during which the sun is too high to take a sextant reading with the artificial horizon; thus, sights should normally be planned for the morning or evening hours.

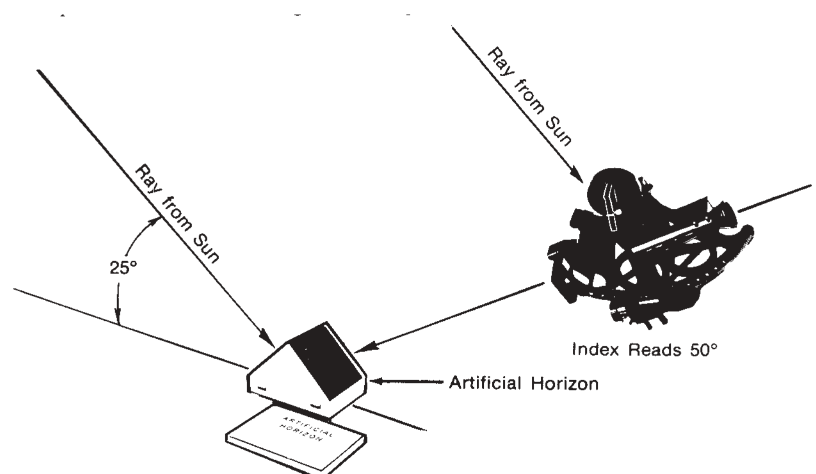
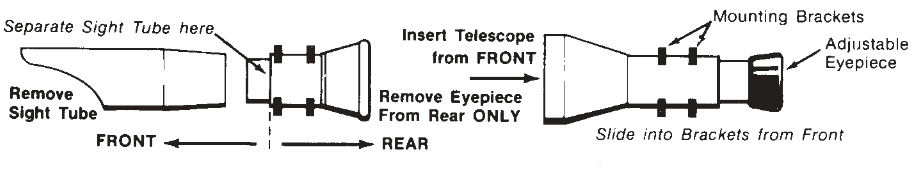


Fig. 14

USING A SIGHT TUBE OR A TELESCOPE

Sextants can come equipped with a hooded sight tube or a telescope. Some models are interchangeable. The Mark 25 sextant comes equipped with a high quality 3X telescope. The telescope is interchangeable with the hooded sight tube. The use of one or the other will respond to your needs and the lighting conditions at the time. An illustration of these two eyepieces is shown below. The mounting system varies from model to model so these illustrations are only for reference.



SEXTANT ADJUSTMENTS

Adjusting your sextant is easy and should be done each time it is used. On a correctly adjusted sextant, the two mirrors are always perpendicular to the frame and become parallel to each other when the body and drum scales read zero.

INDEX MIRROR ADJUSTMENT

First, adjust the index mirror (the large movable mirror at the pivot of the index arm) so that it is perpendicular to the frame. Set the instrument at approximately 50º. Holding the sextant horizontal and about eight inches from the eye, look with one eye into the mirror so that the frame arc is reflected in the mirror. Move the instrument until you can look past the index mirror and see the actual frame arc as well as the reflected arc. The two arcs should appear as one continuous curve. If they do not, turn the adjustment screw at the back of the index mirror (Fig. 2) until the two arcs come into alignment.

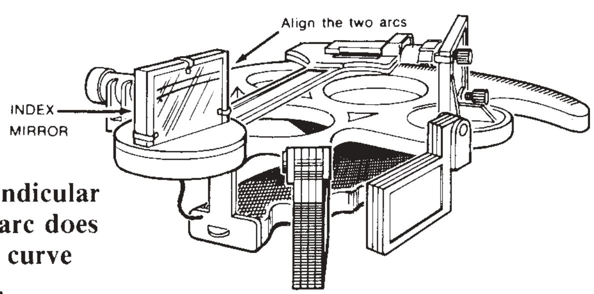


Fig. 2
Index mirror is not perpendicular to the frame — reflected arc does not appear as continuous curve with the actual frame arc.

HORIZON MIRROR ADJUSTMENT

First, adjust for "side error" by making the Beam Converger or the half silvered mirror perpendicular to the frame. Holding the sextant in your right hand,

the declination of the sun from the Nautical Almanac or from the approximate declination values at the end of this booklet.

Finally, calculate latitude by combining the altitude of the sun at local noon with the declination of the sun from the navigation tables (Fig. 13b). Assuming you are north of the sun, the following formula is used in northern latitudes:

Latitude = 90º - Corrected Altitude ± Declination of the Sun

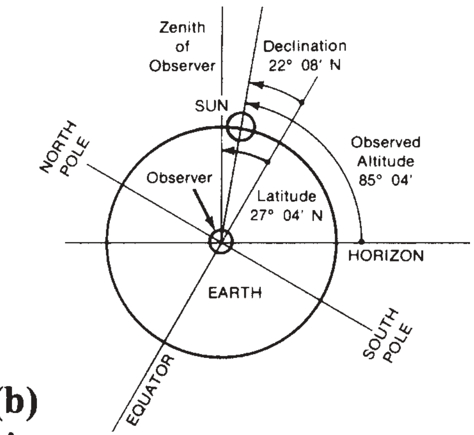


Fig. 13(b)
Latitude Diagram
(View of Earth Looking at Equator)

When the sun is north of the equator, ADD the declination; when it is south of the equator, SUBTRACT the declination.

The presentations here are commonly used by navigators to help insure the accuracy of their calculations.

Example: The Latitude Calculation **Latitude: 2 June**

Step One: Finding corrected altitude of the sun.

hs	84°	56′	Lower limb observation (your sextant reading at local noon)
- IC		5′	Index correction
	84°	51′	
- DIP		3′	Height of eye correction (see Fig. 8)
	84°	48′	
+ ☉		16′	Semi-diameter correction
Ho	85°	04′	Corrected altitude

Step Two: Applying the above formula for latitude

	89°	60′	Altitude of the sun at G.P. (89° 60′ = 90°)
- Ho	85°	04′	Corrected altitude of the sun (from "Step One" above)
	4°	56′	Distance from the sun's G.P.
+	22°	08′ N	Declination of the sun, north of the equator on June 2 (from student tables)
	27°	04′ N	Latitude of observer

With the sextant still held to your eye, turn the screw that is furthest from the frame at the back of the horizon mirror or Beam Converger until the two horizon images move exactly together (Fig. 5).

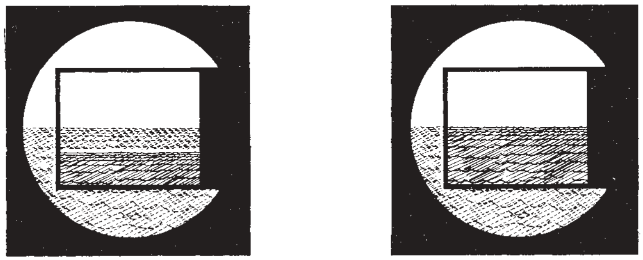


Fig. 5
(a) Beam Converger and Index mirror not parallel. **(b) Beam Converger and Index mirror parallel.**

To be certain that the sextant is now correctly adjusted, check to see that the sextant is still set at 0º 00' and the real and reflected horizons remain in perfect coincidence when the instrument is rocked or inclined from side to side (Fig. 6). You can make small final adjustments to both screws if necessary.

Fig. 6
On a correctly adjusted sextant, the real and mirror horizons remain in a single line when the instrument is rocked from side to side.

While you should know how to adjust your sextant for index error, it is not necessary to remove it entirely. It is standard practice to simply note the error and then correct one's readings for this amount each time the sextant is used. (6' or so of index error is allowable.) To check for index error, hold the sextant in your right hand and look at the sea horizon. By moving the index arm and the micrometer drum, line up the real and mirror horizons so that both appear as a single straight line. Now, look at the sextant scales. If the sextant reads 0º 00', there is no index error. If the sextant reads anything but zero, there is an index error, which must be added to or subtracted from each subsequent sight. For example, if the sextant reads 6', the 6' is

carefully. Take a sight about every three minutes until the sun's altitude is no longer increasing. During meridian passage, the sun will seem to "hang" in the sky for a short period at its highest point, going neither up nor down. Carefully note the sextant reading. This is the sun's altitude at meridian passage. To determine the exact time of local noon, set your sextant at the same altitude as your first sight. Wait for the sun to drop to this altitude, and note the time again. The time of local noon is exactly half way between the times of the two sights.

Record the local time and the sextant reading when the sun was at the highest point. These two readings will serve to locate your position. The time is used to determine longitude and the sextant reading to determine latitude.

THE COMPLETE SIGHT

Let us assume for this example that your ship is sailing from San Francisco to Hawaii and that you have been using the sun to find your position each day. To allow plenty of time to follow the sun up to its highest point, make sure that you have completed all your preparations by 10:00a.m. local time. Your chart shows yesterday's position. From this position, draw a line in the direction you are traveling equal in length to the estimated number of miles to be traveled by noon today. This is your "dead reckoning position" (D.R.), which will be compared with your "noon sight"

Note that you will be standing on deck in such a manner that your eye is ten feet above the water (for Dip correction) and that the index error of your sextant is : + 5'.

At about 11:20 a.m., you begin taking sights. At 11:23:30, your first sextant reading is 82º *56'*. You continue recording the sun's altitude approximately every three minutes until the sun seems to "hang" in the sky, dropping to a lower altitude at your next sight. The maximum altitude of the sun, 84º *56'*, is the altitude of the sun at meridian passage. You continue taking sights until 12:03:30, when the sun has dropped to your original reading of 82º 56'. You know now that the sun reached its meridian at 11:43:30 (exactly half the time between 11:23:30 and 12:03:30). Next, you find the Greenwich Mean Time (GMT) of your local noon by listening to the radio time signal, correcting any error your watch may have had. In this example, you tune in the time signal and find that GMT is now 22:10:00. Your watch reads 12:10:00, so it has no error. You now know that your local noon occurred at GMT 21:43:30 (26 minutes 30 seconds ago).

You now have enough facts to work out your noon sight: the date, the time of meridian passage (local noon), the altitude of the sun at meridian passage, the height of your eye above the surface of the sea, and the index error of the sextant you are using.

FINDING LONGITUDE

Meridians of longitude are measured east or west from the prime meridian (zero degrees) at Greenwich, England. Because the ground position of the sun observer is standing. However, due to the height of the eye of the observer, the visible horizon actually falls below this theoretical place (Fig. 8). To correct for the height of the eye, one must apply a "dip correction". Dip correction increases as the eye is raised further above the surface of the water (Table I) and must always be subtracted from the sextant reading.

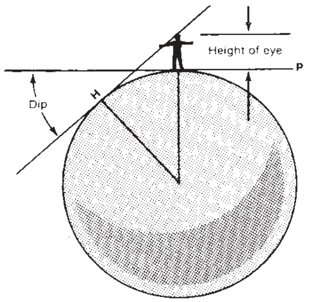


Fig. 8

Table 1

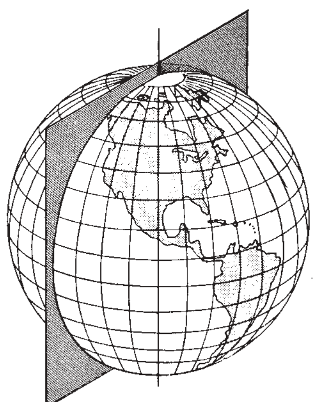
Height of Eye Correction

Feet	Meters	Dip
5	1.5	2′
10	3.0	3′
15	4.5	4′
25	7.5	5′
40	12.0	6′

Due to the height of the eye of the observer, the visible horizon (H) falls below the plane (P) tangent to the earth at the point where the observer is standing.

LATITUDE, LONGITUDE, AND THE NAUTICAL MILE

A great circle is a circle on the surface of the earth, the plane of which passes through the centre of the earth. A small circle is a circle whose plane does NOT pass through the centre of the earth. The equator and the meridians are great circles,



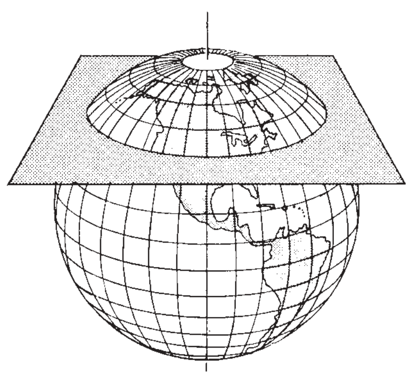


Fig. 9

(a) The plane of a meridian (a great circle) divides the earth into two equal halves.

(b) The plane of a parallel of latitude (a small circle) divides the earth into two unequal parts.

while parallels of latitude are small circles, which become progressively smaller as the distance from the equator increases. At the poles (90º N or S), they are but single points (Fig. 9).

A nautical mile is equal to one minute of arc of a great circle. Since latitude is measured north or south from the equator, it is measured along a meridian (a great circle); one minute of latitude equals one nautical mile anywhere on the earth. Since longitude is measured east or west from the prime meridian (zero degrees) at Greenwich, England, it is measured along a parallel of latitude (a small circle); one minute of longitude equals one nautical mile only at the equator. Approaching the poles, one minute of longitude equals less and less of a nautical mile. (Fig.10)

NOTE: the nautical mile (6076 feet; 1852 meters) is longer than the statute mile (5280 feet; 1609 meters) used on land. The earth measures 21,600 nautical miles in circumference.

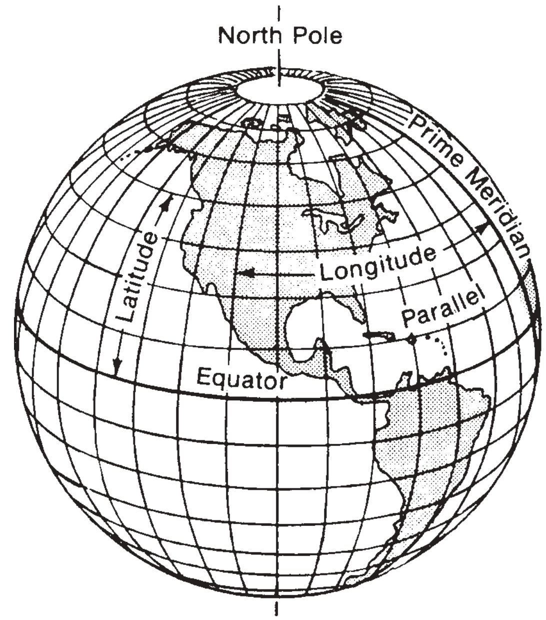


Fig. 10

DECLINATION

Every star and planet, including the sun, has a ground position, i.e., the spot on the earth directly beneath it. Standing at the sun's G. P. (ground position), you would have to look straight up to see the sun; if you were to measure its altitude with a sextant, you would find the altitude was 90^0.

From the earth, the sun seems to move across the sky in an arc from east to west. During certain times of the year, it is "moving" around the earth directly above the equator or, in other words, the sun's G.P. is running along the equator. Declination of the sun at this time is zero. However, the sun's G.P. does not stay at the equator throughout the year. It moves north to a maximum of 23 1/2º N in the summer of the Northern Hemisphere and south to a maximum of 23 1/2º S in the winter. The distance of the sun's G.P. from the equator, expressed in degrees north or south, is known as the declination of the sun (Fig. 11).